Development of a nutritionally balanced pizza, as a functional meal designed to meet published dietary guidelines

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ML developed the concept. EC and ML supervised AJ, who carried out the dietary analysis and reformulation. KA carried out the nutritional analysis. EC, ML and AJ wrote the manuscript, which was approved by all authors.

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Abstract

Objective: To develop a worked-example of product reformulation of a very popular 'junk-food' to meet nutritional guidelines for public health in a ready-meal.

Design: Indicative survey of popular Margherita pizzas, followed by product-reformulation, applying dietary guidelines to generate a single-item pizza meal containing 30% daily amounts of energy and all nutrients. An iterative process was used, first to optimise nutrient balance by adjusting the proportions of bread base, tomato-based sauce and mozzarella topping, then adding ingredients to provide specific nutrients, consumer tasting.

Setting: Urban areas of contrasting socio-economic status

Subjects: Untrained unselected adults (n=49) and children (n=63), assessing pizza at tasting stations.

Results: Most commercial pizzas provide insufficient information to assess all nutrients and traditional Margherita pizza ingredients provide insufficient iron, zinc, iodine, vitamins C and B_{12}. Energy contents of the portions currently sold as standard ranged from 200 to 562 kcal, and most exceeded 30% Guideline Daily Amounts for saturated-fat and sodium when a 600 kcal notional meal was considered.

The "nutritionally-balanced pizza" provides the required energy for a single-item meal (600kcal), with all nutrients within recommended ranges: sodium (473mg, ~45% below recommended level), saturated fats (<11% energy), dietary fibre (13.7g). Most adults (77%) and children (81%) rated it 'as good as' or 'better than' their usual choice.

Conclusions: Nutritional guidelines to reduce chronic diseases can be applied to reformulate 'junk-food' ready-meals, to improve public health through a health-by-stealth approach without requiring change in eating habits.

Introduction

Within contemporary culture, the pizza is commonly regarded as a classic example of "junk food", satisfying a need for convenience (low cooking skills requirement, perceived value for money, short preparation time) [1, 2]. Historically, pizza was made from bread, with tomatoes and a little cheese. It should thus be a low-fat meal containing at least one portion of fruit or vegetable. Moreover, key pizza ingredients have been associated with improved cardiovascular health and cancer [3, 4]. However, to enhance flavour, palatability and ultimately consumer acceptance, pizza recipes include a higher proportion of cheese and salt than desirable [5]. It is also perceived as fattening, calorie-dense and harmful for the heart [4]. As a cheap, mass-produced food, it is also assumed to contain poor quality ingredients and additives. While many pizzas are high in salt [6], their impact on human nutrition does not seem to have been studied, a problem compounded by the limited availability of nutritional content information for commercial pizzas.

As pizzas available on the market are currently mostly nutritionally undesirable, frequent consumption of this single food could result in adverse health effects. Improving pizza compositions (inter)nationally could therefore have a valuable impact on ill-health. Indeed, this strategy was earmarked by Combris et al. as a potential tool to improve public health [7] and food reformulation is a major feature of the Department of Health "Responsibility deal" (England), engaging the food industry to deliver public health goals [8]. Reformulation of commonly eaten foods is key approach to achieving the goals set by the WHO/FAO Expert consulation [9]. Pizza is one of the most popular ready-meals, particularly favoured by adolescents and young adults [10]. The cheese and tomato paste (Margherita) pizza commonly appears on school meal menus as a daily "safe" option, being almost universally liked and accepted. Highly flavoured, warming and filling, pizzas also present advantages for mass-catering as a finger-food which can be pre-prepared, kept chilled or frozen and chosen as a ready meal, street-food or 'carry-out'.

Hitherto, food reformulation efforts have mainly addressed single nutrients, such as salt or trans-fatty acids reduction, and many essential micronutrients under-consumed by the population have been overlooked [8]. Their contents are not required on food labels. Pizza can be served either as a complete, single-item, meal, or as a part, or course of a multi-component meal, and this flexibility has also led to it being considered recently as a potential "functional food" [11]. There is scope to undertake

reformulation of the pizza beyond salt and saturated fat reduction, to impact on the quality of the meal as a whole. The flexibility in the recipe, especially regarding topping choices and to a lesser extent, modification of the dough recipe, also enables the introduction of functional ingredients to achieve an improved nutritional composition [11].

In order to interpret the nutrient contents of meals, it is necessary to relate them to the recommended sizes and compositions of meals, and to the recommended nutrient composition of overall diets. The FSA criteria for the size of a complete meal (potentially including a drink and a dessert as well as side dishes) equates to the amount of food which provides 30% of the recommended daily intake (about 600 kcal) [12]. Initially formulated for situations in which all foods were provided (institutions), it can be extrapolated for specific meals, with the caveat that supply of nutrients may not be uniform over the day. This amount of food, and a proportional amounts of nutrient, is a third of the Guideline Daily Amounts (GDA, providing an indication of how much energy and nutrients can be consumed daily, to be renamed Reference Intakes from 2014 onwards) and is very similar to those as used in the Scottish nutritional recommendations for school meals (Scottish Government, 2008), summarized in Table 1. For most nutrient recommendations, differences between age groups are small, with no hazard from consumption of the 'adult' recommendation by a child. The important exceptions to this are energy and sodium, where there are marked differences in requirement and where overconsumption would have adverse consequences. Therefore, meals designed for, or marketed towards, schoolchildren need to match their nutritional requirements and also their safe limits with regard to energy and sodium.

We have previously shown that the energy contents of other ready-meals meals is erratic (unconsistent and wide ranging within similar lines of products), and their nutrient composition often unsatisfactory [2]. In this paper, we first assess the dietary quality of an indicative selection of contemporary pizzas, and demonstrate how a single-item pizza meal can be redesigned to match the characteristics for a healthful meal according to recently published guidelines. We use the popular Margherita pizza for proof-of-concept.

Methods

Nutritional composition of commercially available pizzas

An indicative selection of 25 popular Margherita pizzas from UK / international suppliers, the most popular variety, was included in this study. A full survey of all pizzas would be impractical, so the pizzas chosen were those available from major food outlets including pizza chains, supermarkets (fresh and frozen section) as well as pizza recipes provided on popular internet sites (bbcgoodfood.com and allrecipes.co.uk) between June 2011 and October 2011. The selection also includes a pizza (Cosmo Ltd.) which is supplied as 60% of school-meals pizzas in Scotland, and for which the detailed recipe was made available.

Nutrient composition of the range of pizzas was explored based on manufacturer information (either on the packaging or the recipe), related to current dietary recommendations [12, 13]. The data are reported for the normal portion or segment size, as sold, with its content in kcal and associated nutrient contents, and also the same data standardized to a 'meal-sized' 600 kcal portion.

Analysis and optimization of a commercial pizza recipe

As a starting template from which to construct a nutritionally balanced pizza recipe, the Cosmo Products Ltd Margherita pizza recipe was analysed using Windiets 2005 (Robert Gordon University, UK). The focus was on energy, macronutrients expressed as %energy (total carbohydrates, non-milk extrinsic sugars, total proteins, total fats and saturated fats), fibre content (g), sodium (mg) / salt (g), iron (mg), folates (mg), zinc (mg), calcium (mg), vitamin A (mg) and vitamin C (mg). Ingredients in the recipe were adjusted to approach the guideline nutrient levels for a meal, as outlined by the UK Food Standards Agency [12].

This recipe was then adapted with the addition of some minor ingredients to finalise a "nutritionally balanced pizza", using only natural ingredients selected for their nutritional profiles. The recipe included a mix of white and whole-wheat flour, fermented naturally with baker's yeast, rapeseed oil, minimal salt, seaweed (Seagreens® *Ascophyllum nodosum*), red pepper, canned and cherry tomatoes, garlic powder, oregano and mozzarella cheese.

Nutritional analysis of the optimized pizza product

Nutritional analyses on the finished product were carried out at Glasgow Caledonian University Food Research Laboratory, which operates to ISO 17025:2005 standards. The pizzas were produced industrially as a batch and two representative samples were randomly selected and sent to the laboratory frozen (transport time less than one 30 minutes, on ice blocks, with immediate transfer to -20˚C on arrival. The pizzas were processed for analysis within a week, cooked in a domestic oven, as it would be for eating, and their energy content determined from the composition of the macronutrients. All measurements were carried out in triplicate. Total carbohydrates were determined from the sum of moisture, fat, protein and ash contents. Moisture content was determined by dry oven method at 103 ± 3^{o}C (BS 4401-3: 1997; ISO 1442:1997); total fat content by drying followed by petroleum ether extraction (BS 4401-4; 1970); protein by determining nitrogen (X 6.25) by Macro-Kjeldahl method (BS 4401-2: 1980; ISO 937:1978) and ash by incinerating at 525 ± 25^{o}C (BS 4401-1: 1998; ISO 936:1998). The total sugar profile (all monosaccharides and disaccharides) was determined by high performance liquid chromatographic method (and NMES estimated by subtracting lactose and galactose) [14]; dietary fibre by AOAC method [15] and fatty acids by capillary gas chromatography [16]. The mineral contents (sodium, calcium, zinc and iron) were determined by atomic absorption spectroscopy [17]. Folates were determined by competitive enzyme immunoassay method (R-Biopharm, 2010), vitamin C by titrimetric method [14] and vitamin A by liquid chromatography [18].

Evaluation of the acceptability of the finished product

Taste tests and acceptability evaluations were conducted with untrained members of the public (both adults and children) at two different public locations around the city of Glasgow. Acceptability of the product was established using the 9-point hedonic scale, ranging from 1 (dislike extremely) to 9 (like extremely) [19, 20]. The scale was modified for children according to Kroll, and descriptors ranged from 1 (‘super-bad’) to 9 (‘super-good’) [21]. The pizza was assessed for its taste and its appearance, with a further scale for overall acceptability. Tasters were also asked to compare the pizza to their usual one (not as good, as good as, or better), whether they would buy it (adults) or eat it (children) rather than their usual one (possible answers were “yes”, “no”, “not sure”) and were asked to describe what they liked best or liked least about the pizza. Furthermore, adults were asked how much more they would be willing to pay for a nutritionally balanced pizza.

Results and discussion

Nutritional composition of a selection of Margherita pizzas

The recommendations for a nutritionally balanced meal (Table 1) can be related to nutritional values for the 25 pizzas (Table 2). There was considerable variation in the nutrient compositions of what might appear, from the on-label descriptions, to be the same pizza. Energy contents of the portions currently sold as standard vary from 200 to 562 kcal. Few currently approach the energy content required for a meal, even for primary school-children. Most have substantially lower serving sizes than a standard meal, implying that none would be suitable as single-item meals, and that an additional food item would be required to form a meal of about 600 kcal. No guidance was offered as to what type of additional items should be eaten to achieve nutritionally-balanced meal. Given the range of energy content (200 to 562 kcal per pizza portion), it will be difficult to make a consensus decision on acceptable additional meal items.

Considering that pizza is commonly eaten as a stand-alone meal, we also analysed the nutrient composition of a notional 600 kcal serving of each pizza studied. The main nutrient information, often available on product packaging and relevant to healthy eating, is on saturated fat, carbohydrate, fibre and salt (sodium). New labelling legislation (under the EU Food Information for Consumer Regulation), effective from 2016 onward, will make back-of-pack nutritional information mandatory for these nutrients . Overall, our results are in line with a previous survey of pizzas [22]. Perhaps surprisingly, only 6 of the 25 pizzas contain too much total fat (>35%E). The other 19 values are often close to the limit but within the recommendations. On the other hand, only 2 pizzas in the selection contain a desirable proportion of saturated fat, i.e. below 11% of the energy [12]. Nineteen of the 25 (76%) had saturated fat contents above 11%E, and many were close to the recommendation e.g. 11-15%E, but only 8 were very high, above 15%E. The range of saturated fat contents, from 4.3 to 22.9%E was wide, indicating considerable scope for improvement by recipe modifications. Most of the fat and saturated fat comes from the cheese topping, with a small contribution from oil.

The amount of sodium in most of the 25 pizzas is substantially above the recommended limit for a meal (Table1). The source of sodium is mainly the cheese topping, although extra salt is also routinely added

187 to both dough and sauce topping. Nine of the 25 pizzas contained over 1g sodium per 600 kcal serving.
188 On the other hand, several of these pizzas (all standard pizzas, not part of a healthy range or making a
189 'low-sodium or low-salt' claim), have contents well within the recommended limit. Again this indicates
190 that there is scope to modify the current recipes, and remain commercially successful, with a much
191 lower sodium content.

192 To constitute a healthy nutritionally balanced meal, at least 45% of the energy intake should come from
193 carbohydrates (Table 1). Only 5 pizzas in 25 fail to reach this proportion, mainly because their fat and
194 protein contents (combined) are too high. The quantity of fibre in these pizzas varies very substantially
195 from 2.1 to 9.2g/600 kcal serving. This variation depends on the source and quantity of tomato and
196 flour used. Other ingredients supply little or no dietary fibre.

197 The compositional values for vitamins and minerals are usually absent from the nutritional information
198 tables provided on pizza packaging. These values were provided for only five pizzas out of the 25 for
199 which recipes are provided, and limited information for three others from the commercial range. For
200 these eight pizzas, vitamin contents varied widely, with none meeting the combined nutritional
201 recommendations for iron, vitamin C and vitamin A (Table 3). Only one pizza met the recommended
202 value for iron, and two the recommended value for vitamin C. Recommendations for vitamin A were
203 met by four out of the eight pizzas, while all but one met recommendations for calcium.

204 Our overview of these 25 Margherita pizzas indicates that, while none of them match all the nutritional
205 recommendations for a healthy meal, many already meet several of the criteria, with several more
206 being close to all criteria. The energy contents of commercial portions however vary and may not
207 match consumer needs, depending on whether the pizza is consumed as a single item meal or not. If
208 not, side-item selection may be difficult with variable energy content of the different pizza products.
209 There is clearly wide variation in the "healthfulness" of commonly available pizzas in relation to
210 cardiovascular risks – e.g. saturated fat content ranging between 4.3 to 22.9% of energy and sodium
211 from 526 to 1558 mg in a 600 kcal "meal-sized" portion. However, there is also clearly scope, using
212 traditional ingredients, to modify recipes to meet nutritional targets.

213 Bearing in mind the frequency of pizza consumptions by young people, and the documented prevalence

of nutritional deficiencies in young people (particularly iron, calcium, magnesium, vitamin A [23], there is a clear case for trying to apply the nutritional standards which already exist for meals (Table 1). If it is practically and commercially possible for pizzas to provide these nutrients, there seems no reason to continue to make nutritionally unbalanced pizzas.

Dietary modification of a commercial pizza recipe to achieve a balanced meal

To explore the possible ways to provide a nutritionally balance pizza-meal, the Margherita recipe currently used by a local pizza manufacturer (Cosmo Products Ltd, UK) was examined in more detail (Table 3). The pizza, made using a traditional recipe and method, is currently sold as a half-pizza portion (9 inch diameter), containing about 400 kcal. It is acceptable for the primary and secondary school market, where the average energy per meal is either 557 or 667kcal, respectively, if consumed alongside a starter and/or a pudding. The current total fat content, as a proportion of total energy of the pizzas itself, is just acceptable, at the limit of 35%E (which, based on the 1991 COMA Report, would apply to the fat intake of a population over several days, and is not designed to be a limit for a single meal, yet a potential useful benchmark [29]), but the proportion of energy from saturated fat is too high. A 600kcal portion would contain too much sodium and protein, and too little iron and vitamin C (based on the Dietary Reference Values set in the 1991 COMA Report, designed for population intake and not designed for single meals, as mentioned above).

The pizza recipe was reformulated to a prototype balanced pizza, for which the nutrient composition is shown in Table 4. While a useful source of calcium and vitamin A, the mozzarella cheese on the pizza is also the main source of saturated fat and protein and contributes to the overall sodium content. To reach an adequate proportion of saturated fat, the quantity of mozzarella was reduced, hence a relative increase of the bread-to-topping ratio. Salt was decreased in both dough and sauce. Addition of red peppers mixed into the tomato sauce enable to reach the recommended vitamin C. Incorporating whole-wheat flour and a small amount of dried seaweed to the dough achieved the recommended quantity of fibre, iron and vitamin A, and also increasing the iodine and vitamin B12 content of the pizza.

The values obtained for the prototype recipe, using standard tables of nutrient compositions (Windiets

2005), were confirmed for a range of nutrients by laboratory analyses using standard methods, and compared to the FSA guidelines for nutrient composition of the adult meal. The outcome of the laboratory analyses were similar to those values obtained using food tables for many nutrients, but varied significantly for vitamin C, folate, Ca, Na, probably due to factors such as variability of the nutrient composition of the key ingredients, and the impact of processing / cooking on some vitamins. Heat processing may increase the concentrations of some nutrients due to loss of moisture, but reduces others through compositional changes such as Maillard reactions and loss of volatiles (eg iodine) or heat-sensitive nutrients. Comparison of each nutrient with the FSA guideline highlighted that energy, carbohydrate, vitamin C and sodium varied either marginally or significantly from the guidelines. The prototype pizza recipe was then modified to address these departures from guidelines, and the nutrient composition of the final recipe was confirmed using standard tables of nutrient compositions (Windiets 2005). The sodium content, shown by laboratory analysis to be significantly higher than expected in the prototype, was re-confirmed in the final product by atomic absorption spectroscopy (at an acceptable level of 427.5 mg per pizza). Tables 4 and 5 show nutrient contents across the steps taken from the original template, through to prototype and final pizza recipe.

Acceptability of the reformulated balanced pizza

The reformulated pizza is only slightly different in appearance and virtually identical in taste to the original pizza recipe, and is still prepared using the traditional Italian baking methods. A total of 63 children and 49 adults, in two locations within Greater Glasgow (West End and Clydebank), tasted the pizza and filled the feedback form. The median age for children was 9 years (IQR 4, range 3-14) and for adults 35 years (IQR 16.5, range 19-70). The gender split was 59% females and 41% males for children, and 69% females and 31% males for adults.

The pizza was rated very highly for both appearance and taste by both children and adult tasters, achieving modes of 9 and 8, respectively, with narrow inter-quartile ranges (2 and 1, respectively) (Table 6). Among the children, 46% rated the pizza as good as their usual one, and 35% better (ie 81% at least as good as), and 41% would eat the pizza instead of their usual one. Most adults (57%) rated the pizza ‘as good as’ their usual one, with 20% better (ie. 77% found it at least as good as their usual pizza): 69% of the adults would buy it instead of their usual one. Most would be willing to pay an

extra 50 pence for a nutritionally balanced pizza.

The children liked best the taste (48%) and the cheese (19%), while the adults liked best the taste (39%) the dough / base (20%) and the tomatoes / sauce (16%). About a third (30%) of children responded "nothing" when asked what they liked *least* about the pizza with other children mentioning that they liked least the tomatoes / sauce (14%), appearance (11%) or dough / base (10%). About a quarter of adults (27%) responded "nothing" when asked what they liked *least* about the pizza, others mentioning that they liked least the base / dough (31%), or taste / lack of taste (12%).

This study shows that, perhaps contrary to popular opinion, it is perfectly possible to have an attractive, nutritionally-balanced meal, as a single-item pizza meal. Indeed, sensory attributes (appearance, flavour, odour) have been shown to influence the likelihood of consumer purchasing reformulated healthier ready-meal versions [24]. The high consumer acceptability of this product is therefore vital, and consistent with previous research showing that altering the amount of cheese and crust on a regular pepperoni pizza had no detrimental impact on consumer acceptance of the product [25].

The balanced pizza – potential for health by stealth

In the case of the popular Margherita pizza, it was possible, although quite difficult, to reach all the recommendations within a feasible pizza portion size. We specifically applied this approach to a single-item pizza meal and achieved that through subtle, and essentially undetectable, modifications to the traditional recipe, and the incorporation of small amounts of functional ingredients, specifically red pepper and seaweed (affording an improved nutritional composition to the Margherita pizza, and broadening its polyphenolic and carotenoid profile, beyond traditional ingredients). However the physical size, or bulk, of a 600-667 kcal meal-sized portion may be too large for some consumers. An alternative two-component solution, also allows the design of nutritionally balanced Margherita pizza-based meals by adding another item, like a side serving of salad or vegetables, a yoghurt or a piece of fruit. Both of these solutions could be achievable within current meal pricing, in economy price ranges. And they should immediately become the preferred pizzas for health promotion and for provision for schools and other mass-catering. There is no justification for supplying nutritionally undesirable alternatives.

Historically, salt played a key role in the taste of the pizza, in days when salt was added to most foods, as well as a role in the process of bread-making. By its hygroscopic properties, salt improves indeed the plastic properties of the dough during the dough mixing, and it allows a better preservation after baking too. With modern temperature-controlled ovens, this function from salt is less necessary. The lower sodium contents of other successful pizzas indicate that it is possible to reduce the content to within the recommended limit.

The main source of vitamin C in the Margherita pizza is tomato, but tomato is in fact a relatively poor source of vitamin C. To reach the recommended amount of vitamin C, the amount of tomato would be impractically large, so the addition of another item was necessary. Red pepper is a convenient, and cheap, ingredient, rich in vitamin C, which we was added in small amounts to the tomato sauce. This was shown not to affect taste or acceptability.

Iron deficiency is a common problem in young and older people alike [12], and the low iron content, common to all Margherita recipes, is problematic if only the traditional ingredients are used. The amount required for a nutritional-balanced meal is substantially greater than currently present, and can only be reached by adding an ingredient which is very rich in iron, but which does not corrupt the other nutrient balances looks, taste or practical issues around baking. Most ingredients rich in iron would significantly change the appearance and taste of a Margherita pizza, either by radically increasing the amount of bread base with extra wheat-flour, or by adding meat which is not acceptable to many and certainly no longer 'Margherita'. Meat such as ham would add further to the sodium and fat contents. Using a small amount of *Ascophyllum nodosum,* a common seaweed in UK and Europe, enabled to achieve the required target for iron. In addition, the seaweed used here (Seagreens®) is a source of vitamin A, calcium as well as iodine (a nutrient lacking in the British diet) [26].

Health promotion based on nutritional education only has had rather little impact and a more potent alternative strategy lies in modification of the food supply [7, 27, 28]. Achieving meeting nutritional guidelines by stealth – via reformulation of common foods rather than education-based strategy only is indeed promising, but this has not been supported in general by the food industry. There is however scope to modify the composition of specific products and the present project appears to be the first to have done so for a single-item meal. The process we have demonstrated is versatile and lends itself to a

range of nutritionally balanced pizza meals beyond the simple Margherita. Commercial opportunities lie in the creation of premium range of pizzas for the health-conscious customer seeking convenience and taste. We have demonstrated that nutritionally-balanced pizza recipes are achievable and suggest that these should become the standard to which all others would aspire: in principle there is no reason for continuing to sell nutritionally unbalanced pizzas; It will therefore be important to extend the type of work presented here to different recipes and among wider consumer groups to test acceptability. When respected public bodies such as the BBC publish recipes on their websites, it would serve the public best for those recipes to be considered from a nutritional perspective.

A nutritionally-balanced meal may still require a degree of moderation when consumed. The weight-conscious consumer must limit himself/herself to the 600 kcal serving of pizza-meal, and avoid unwanted energy intake from high-calorie snacks and drinks which are currently heavily promoted at pizza outlets. For example, a full-fat latte coffee (340 ml) contains about 200 kcal, and a standard serving of carbonated cola or 'soda' (33cl) contains about 140 kcal. While a full pizza may provide the required energy and nutrients for a meal, it does not stop consumers exploring a range of meal compositions, including for example side-salad and fruits to accompany a portion of the pizza. Indeed, here we described a single-item pizza meal. However, this is only one way to ensure that recommendations are met. Most consumers are failing to achieve the FSA guidelines at present, under advice that meals need not all be nutritionally balanced but should complement one another to construct a nutritionally balanced overall diet. The single-item pizza meal presented here is an innovative solution, never offered previously, and which might be appropriate for some consumer sectors.

Conclusion

The data presented here suggest that there is scope to improve ready-meals, which are currently mostly nutritionally unacceptable. There is increasing pressure for food manufacturers to limit the amount of sodium added to these products, and to adopt a more health-conscious approach when formulating products. The nutritionally balanced pizza was developed with industrial partners and has successfully reached market. The results of this study confirm that consumers are willing to adopt nutritionally balanced pizzas, providing opportunities for the food industry to develop tailor-made, functional

products, thereby increasing their innovation and competitiveness.

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Table 1: Recommended intakes for lunches or dinners, for Scottish primary school pupils, secondary school pupils (Scottish Government, 2008) and adults (FSA, 2007).

	Primary school pupils aged 5-11 [13]	Secondary school pupils aged 11-16 [13]	Adults aged 19-55 [12]
Energy (kcal)	557	667	600
Proteins (%E)		> 12 %	
CHO (%E)		45-60 %	
Sugar (%E)		< 11%	
Fat (%E)		20-35 %	
Saturated Fat (%E)		< 11 %	
Sodium (mg)	< 686	< 824	
Iron (mg)	> 3	> 4,4	
Folates (µg)	> 45	> 60	
Zinc (mg)	> 2.1	> 2.8	
Dietary fiber (g)	> 4.8	> 6.3	> 7.5
Calcium (mg)	> 165	> 300	> 270
Vitamin A (µg)	> 150	> 187	> 210
Vitamin C (mg)	> 9	> 11	> 12

%E: % of the energy intake

Table 2: Nutritional values for macronutrients in a selection of 25 Margherita pizzas, both for a portion sold as standard, and as a 600cal portion.

Figures which lie outside the nutritional recommendations for adult meals are highlighted, either above (†) or below (ɸ).

Pizza	Portion (kcal)	Prot. (%)	CHO (%)	Sugar (%)	Fat (%)	Sat. Fat (%)	Fiber (g)	Sodium (mg)
Amy's Margherita Pizza (organic) 368g, USA	280 (⅓)	15.7	45.7	4.3	38.6†	11.3†	2	550
	600						4.3	1179†
Compliments Mozzarella Pesto Thin Crust Pizza Brick Oven Pizza 336g, CA	200 (¼)	20	48	6	31.5	13.5†	2	320
	600						6	960†
Conte's Margherita Pizza with Roasted Garlic and Olive Oil 452g, USA	220 (¼)	14.5	45.5	7.3	36.8†	14.3†	1	550
	600						2.7	1500†
Cosmo Pizza Margherita 380g, UK	396 (½)	20.1	48.6	1.1	34.5	15.5†	3.9	676
	600						6	1001†
Dietary Specials Mozzarella and tomato Deep Pan Pizza 310g, UK	370 (½)	9.4ɸ	70.5†	4.0	18.3ɸ	4.3	3.4	960
	600						5.5	1558†
Dr.Oetker Ristorante Mozzarella Pizza,	441*	16.6	36.7ɸ	2.7	46.5†	16.1†	2.8	800
	600						3.8	1088†
Goodfellas Deep Pan Margherita Pizza 410g (frozen), UK	249 (¼)	17.6	52.5	6.7	30	14.8†	2.4	310
	600						5.9	765†
Goodfellas Thin Flatbread Light & Crispy Pizza Margherita 345g (frozen), UK	245 (¼)	15.9	50.3	5.2	26.5	11.7†	1.9	340
	600						4.6	842†
Goodfellas Stonebaked Thin Margherita Pizza 345g (frozen), UK	256 (¼)	18.5	42.8ɸ	4.7	38.7†	18.4†	1.7	340
	600						4.0	805†
Kashi Thin Crust Pizza Margherita 339g, USA	260 (⅓)	21.5	44.6ɸ	6.2	31.2	13.8†	4	630
	600						9.2	1454†
McCain Family Pizza Margherita 500g, AU	330 (¼)	19.9	42.9ɸ	10.3	34.2	22.9†	-	438
	600							797†
Pizza Express Margherita 245g, UK	287 (½)	17.4	55.9	4.1	26.5	13.5†	3.3	620
	600						7	1290†
Prima Fresco Margherita 411g, UK	515 (½)	15.8	49.1	5.9	34.9	11.2†	3.9	600
	600						4.6	720†

Tesco Finest Margherita Pizza 306g, UK	410 (½)	17.9	46.7	4.6	33	17.3†	2.8	700†
	600						4	1111†
Tesco Italian Margherita Pizza 310g, UK	420 (½)	17.3	51.4	4.6	29	13†	1.6	600
	600						2.2	889†
Tesco Italian Stonebaked Margherita 445g, UK	310 (¼)	19.3	50.6	4.3	28.9	12.8†	1.1	500
	600						2.1	857†
Domino's Pizza Cheese & Tomato - Delight Mozzarella - Medium Regular Crust 503g, UK	326 (¼)	24.7	54.4	6	20.8	8	3.4	560
	600						6.3	1019†
Domino's Pizza Cheese & Tomato – Medium Regular Crust 504g, UK	324 (¼)	20.9	52.3	6.8	26.6	12.3†	3	500
	600						5.6	934†
Domino's Pizza Cheese & tomato – Medium Thin Crust 369g, UK	320 (¼)	18.1	41.7ϕ	4	40.2†	15.6†	2.8	320
	600						5	605
Pizza Hut Restaurant Margherita Regular Italian	340 (⅓)	16.9	49.4	3.8	32.3	13.8†	-	520
	600							918†
Pizza Hut Restaurant Margherita Regular Pan	376 (⅓)	16	42.6ϕ	2.3	41.6†	14.8†	-	536
	600							855†
allrecipes.co.uk "Easy Pizza"	308 (½)	19.5	51.3	6.3	32.4	19.7†	1.8	345
	600						3.5	672
allrecipes.co.uk Margherita Pizza	257 (¼)	15.2	57.6	4.7	28.8	12.1†	2.2	226
	600						5.1	526
bbcgoodfood.com Ultimate Pizza Margherita	562 (½)	18.2	54	3.5	31.2	16.5†	4.4	1120†
	600						4.7	1196†

** : portion size sold as standard in France, Greece, Ireland, UK. Portion size sold as standard in Canada: ¼ pizza (220cal), USA: 1/3 pizza (290), Germany, Spain: 1 pizza (891).*

Table 3: Nutritional values for micronutrients of the selection of Margherita pizza. Figures which lie outside the nutritional recommendations for adult meals (defined by a 600 kcal portion) are highlighted, either above (†) or below (Φ).

Pizza	Portion (kcal)	Iron (mg)	Folates (µg)	Zinc (mg)	Calcium (mg)	Vitamin A (µg)	Vitamin C (mg)
Amy's Margherita Pizza (organic) 368g, USA	*280 (⅓)*	*1.5*			*54.1*	*42.0*	*1.6*
	600	3.14Φ	-	-	116Φ	90Φ	3.4Φ
Compliments Mozzarella Pesto Thin Crust Pizza Brick Oven Pizza 336g, CA	*200 (¼)*	*1.5*			*90.0*	*42.0*	*2.4*
	600	4.4	-	-	270	126Φ	7.2Φ
Conte's Margherita Pizza with Roasted Garlic and Olive Oil 452g, USA	*220 (¼)*	*0.3*			*163.7*	*38.3*	
	600	0.8Φ	-	-	491	115Φ	-
Cosmo Pizza Margherita 380g, UK	*396 (½)*	*2.2*	*50.8*	*2.4*	*246.2*	*141.2*	*2.4*
	600	3.3Φ	77	3.6	373	214	3.6Φ
Kashi Thin Crust Pizza Margherita 339g, USA	*260 (⅓)*	*1.2*			*179.8*	*69.8*	*4.0*
	600	2.7Φ	-	-	415	161Φ	9.2Φ
allrecipes.co.uk "Easy Pizza"	*308 (½)*	*1.5*	*50.8*	*1.8*	*282.8*	*200.7*	*2.6*
	600	3Φ	99	3.6	551	391	5Φ
allrecipes.co.uk Margherita Pizza	*257 (¼)*	*1.3*	*38.1*	*1.1*	*146.1*	*100.7*	*6.0*
	600	3Φ	89	2.5Φ	341	235	14
bbcgoodfood.com Ultimate Pizza Margherita	*562 (½)*	*2.7*	*86.2*	*2.9*	*400.0*	*296.9*	*13.1*
	600	2.9Φ	92	3.1	427	317	14

Table 4: Nutrient contents, estimated from food composition tables (Windiets 2005) and by laboratory analysis for the prototype balanced Margherita pizza and the final retail product.

Nutrient	Prototype recipe			FSA guidelines (adı		Final recipe
	Dietary analysis (per pizza)	Laboratory analysis (per cooked pizza)†				Dietary analysis (per pizza)
Energy - kJ/kcal	2797 / 664	2810 / 667	(34 / 14)	600	*	2163 / 513
Fat - %E	29.3	19.6	(0.4)	20-35		27.3
SFA - %E	11	6.5	(0.4)	<11		10.2
Prot - %E	17.8	21.4	(0.7)	> 12		17.2
CHO - %E	56.8	67	(2.7)	45-60	*	56.2
NMES - %E	1.3	3.4	(0.5)	<11		2.9
NSP + DF - g	8.5	13.7	(2.6)	>7.5		7.5
VitA - µg	343	427.5	(34.2)	>210		465
VitC – mg	13.3	11.7	(0.6)	>12	*	27.8
Folates - mg	96	62.7	(3.1)	>60		194
Ca - mg	349	547.2	(14.3)	>270		280
Na - mg	817	1023.2	(17.1)	<824	**	473
Fe - mg	4.9	6.4	(0.6)	>4.4		5.3
Zn - mg	3.8	5.8	(0.3)	>2.8		3.5

* These nutrients were deemed to vary too much from the FSA guideline. The prototype recipe was modified to correct this, and validated by Windiet dietary analysis only.

** This nutrient was deemed to vary too much from the FSA guideline. The prototype recipe was modified to correct this, and validated by both Windiet dietary analysis and laboratory analysis.

† Results expressed as mean (standard deviation (SD)). Results are representative of triplicated analysis of duplicate samples.

Table 5: Full nutritional analysis, estimated from food composition tables (Windiets 2005) of the final reformulated nutritionally balanced Margherita pizza.

Nutrient	Unit	Dietary analysis (per pizza)		30% DRV / RDA
Energy	kJ / kcal	2163 / 513		600kcal
Fat	g / %E	15.7	27.3 %E	21
SFA	g / %E	6	10.2 %E	6
PUFA	g / %E	2.9	5.1 %E	
Monos	g / %E	5.5	10.2 %E	
Prot	g / %E	22.2	17.2 %E	13.5
CHO	g / %E	76.1	56.2 %E	69
Total Sugars	g / %E	7.3	5.1 %E	27
NMES	g / %E	3.9	2.9 %E	
NSP + DF	g	7.5		7.2
VitA	µg	465		240
VitC	mg	27.8		24
VitD	ug	0.1		1.5
VitE	mg	4.4		3.6
Thiamin	mg	0.6		0.3
Riboflavin	mg	0.4		0.42
Niacin	mg	10.6		4.8
VitB6	mg	0.6		0.4
Vit B12	µg	0.7		0.8
Folates	µg	194		60

Pantenic acid	mg	1.4	1.8
Biotin	ug	13.5	15
Ca	mg	280	240
Mg	mg	112	112.5
Na	mg	473	720
K	mg	813	600
Cl	mg	816	240
P	mg	413	210
Fe	mg	5.3	4.2
Zn	mg	3.5	3
Cu	mg	0.65	0.3
Mn	mg	2.11	0.6
Se	µg	7	16.5
I	µg	678	45
Cholesterol	mg	23	100
Retinoids	µg	98	
Carotenoids	ug	1131	

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Table 6: Acceptability of the reformulated pizza by members of the public: data on a scale 1-9, presented as mode (IQR)

	Children (n=63)	Adults (n=49)
Appearance of the pizza	9 (2)	8 (1)
Taste of the pizza	9 (2)	8 (1)
Overall score	9 (2)	8 (1)